



# PREVENTING THE PREVENTABLE: The 2015 Tianjin Explosions

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Cover photograph: Voice of America, August 13, 2015, in public domain

In the spelling and order of the names of Chinese authors in the notes, we follow the arrangement of the reference being cited; for clarity, we repeat both last and first names of Chinese authors in their second reference.

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# Preventing the Preventable: The 2015 Tianjin Explosions

## Case Study Scenario: January 2016

The explosions at the Ruihai warehouse yard in the Binhai New Area in Tianjin in August 2015 resulted in the tragic loss of 173 lives and destroyed hundreds of homes and businesses in the area.

Binhai is known for its many industries and shipping areas, offering efficient “factory-to-port” systems. It is also home to millions.<sup>1</sup> The Summer Davos’ website predicted that “in the long run, Binhai New Area will become an ecological livable urban district with economic prosperity, social harmony and beautiful environment.”<sup>2</sup> As of 2014, its man-made beach was the longest beach in China.<sup>3</sup> Tianjin, one of the most populous cities in China,<sup>4</sup> has been the flag-bearer for modern China’s economic prowess—the port for Beijing, home to the Summer Davos, a site for the Olympics, and one of the largest ports in the world. The accident was a significant and embarrassing setback to the government.

Now, after months of investigation, consultations with task forces of experts, and preliminary presentations to the State Council and to Premier Li and President Xi, the state investigation team was finalizing their recommendations. Ms. Wang Jie, a deputy director at the State Administration of Work Safety (SAWS), saw this as one of the most important phases of their work.<sup>5</sup> [Ms. Wang Jie is a fictional character, but the Chinese State Administration of Work Safety and all the other organization and people named in this case study are real.]

Her memory of the event was still fresh. She remembered vividly the sights and sounds from the aftermath of the explosion: the bodies of the young firefighters being pulled out of the rubble; their devastated families; line after line of burnt-out cars, the workers’ dormitories flattened, the roof blown off the train station, the streets covered with glass, the cracks in the apartment blocks, the 100-meter crater in the ground, and all the displaced and worried people.

For days after the explosion she had taken the high speed train from Beijing to Tianjin to help with the response and to ensure there was no more loss of life. For days they looked for bodies, only giving up one month after the accident, in mid-September. There were fears of cyanide leaking into the water table and they had attempted to block all drainage from the site.

Within a few days of the accident, Ms. Wang had been tasked with organizing the investigation, making sure that clues were not lost in the clean-up. She had helped draft the early public statements in the aftermath of the accident that pointed to disregard of safety regulations, problems with the export and import of dangerous cargo, and difficulties in emergency response to the accident.<sup>6</sup> The investigative team was now getting ready to finalize their recommendations before the report would be publicly

released. The highest levels of government were on alert and they wanted to move swiftly—China’s reputation was at stake. What should the government do to prevent such an accident from ever happening again?

Executive Vice Minister of Public Security Yang Huanning headed the inquiry. He had asked Ms. Wang to review the recommendations before the meeting. It was important to have a firm grasp on what had happened in order to plan better for the future. Ms. Wang thought of the people of Tianjin and all the questions they had raised during the investigations. They held up pictures of young men and destroyed homes: Did my son have to die? What will happen to my home? Is the air safe to breathe? Is the water safe to drink? How could such a dangerous facility be so close to where my child sleeps? Why did the firefighters not know what was in the warehouses? Is that why so many died? How did this happen?

## **Part I: The Beginnings**

### **Tianjin: “Growing fast and going global”**

“Modern Tianjin,” “Charming Tianjin,” “Historic Tianjin,” “Gateway to the North,” and “Glamorous Tianjin” are just a few of the terms associated with Tianjin.<sup>7</sup> Host to the World Economic Forum’s “Summer Davos” five times since 2008, also host to twelve Olympic football matches in 2008, Tianjin in 2015 was home to over 15 million people, having grown from 10 million in 2003.<sup>8</sup> Tianjin lies to the south-east of Beijing, 120 kilometers and a half-hour high-speed train-ride away. Tianjin has risen further in prominence as plans to create a large urban area comprised of Beijing, Tianjin, and Hebei Province have started to come to fruition.<sup>9</sup>

Tianjin has two city centers.<sup>10</sup> The first is downtown, with a smattering of late nineteenth-century European buildings, modern skyscrapers, new shopping centers, world-class universities, large hospitals, and a maze of bridges over the Haihe River. Klaus Schwab, founder of the World Economic Forum, compared his boat trip on the Haihe River to one on the Seine. “The Seine is beautiful,” he said, “but it feels better to tour around Haihe.”<sup>11</sup>

Located about 50 kilometers (30 miles) to the east of the downtown city center is the Binhai New Area and Tianjin Port, which lies on Bohai Bay. Together, the Binhai New Area and the port, they constitute the city’s other focal point. Since the 1990s, after obtaining special status with tax breaks and opportunities for less regulation, the Binhai area has grown rapidly.<sup>12</sup> Along Bohai Bay (situated in the Yellow Sea across from the Korean peninsula), the Binhai New Area spans 2270 square kilometers, has 153 kilometers of coastline, and was home to 2.97 million people in 2016.<sup>13</sup> Much of the land is reclaimed from salt marshes—most notably an eco-livable complex built in cooperation with Singapore.<sup>14</sup> Binhai has access to rich natural resources with significant petroleum and natural gas deposits in the Bohai Sea that have helped create a flourishing chemical engineering industry.<sup>15</sup> Other industries include automotive, steel,

microelectronics, and alternative energy. Binhai prides itself on innovation: in 2015, it vaunted makerspaces, creative industries, and a new cow-cloning enterprise.<sup>16</sup>

Tianjin Port, the world's tenth largest port in terms of container throughput and the fourth largest in cargo throughput, is an artificial deep-water port located in the Binhai New Area.<sup>17</sup> Critical to the region's development, the port has trade relationships with 500 ports across 180 countries. At the time of the disaster, the port's administrative functions were managed by the Tianjin Municipal Transportation Commission. Tianjin Port Group was responsible for the development and operations of the port. Several special regulations, including the Port Free Trade Zone (1991), and the Tianjin East Free Port Area (2007) helped the quick movement of goods in and out of the port, cutting through layers of red tape. The Tianjin (Pilot) Free Trade Zone (2016) established a one-stop-shopping system for various licenses.<sup>18</sup>

By 2015, Tianjin led northern China's market-friendly policies and attracted large foreign investments.<sup>19</sup> More than 200 global Fortune 500 companies were based in Binhai and the Tianjin Port.

## **Ruihai**

Tianjin's brew of fast change, innovation, market opening, and service offered entrepreneurs many opportunities to start new businesses. At a dinner party in 2012, Yu Xuewei, an executive with the state-owned Sinochem, met Dong Shexuan, a salesman with connections at the port. They started talking. Mr. Yu knew the industry and management; Mr. Dong had the connections—his father was the chief of police for Tianjin Port. They conceived of a new enterprise that would offer efficient service, cut through red tape, allow companies to ship goods faster. As a private company they could do better, they thought. They would be contributing to the new China and making money for themselves. On November 28, 2012, the two men established the Dongjian Bonded-Port Ruihai International Logistics Company (henceforth Ruihai).<sup>20</sup>

Acquiring 11 acres at the port, Mr. Dong and Mr. Yu began to get the permits to build their warehouse and operate their logistics company. Because Mr. Yu had been prominent at Sinochem, he asked his cousin to be the name of record for his shares.<sup>21</sup> Similarly, Mr. Dong thought it might look bad for his father if his ownership of the company came to light, so he had a friend do the same. Mr. Dong and Mr. Yu were able to use their connections to obtain licenses for the company.<sup>22</sup> They were known trusted entities. When Mr. Dong needed fire department approval, he met with the Tianjin Port fire group, gave them his files, and soon had the approval. When Ruihai needed a permit for land use and the construction of the warehouses from the Binhai New Area Bureau of Planning and Land Resources Administration, the Bureau "referred to the fire safety documents, which had given the green light in terms of the warehouse [being] a safe distance from the residential area."<sup>23</sup> But all was not smooth sailing. They had to have an environmental impact assessment and their location was a problem. The first company Mr. Dong asked turned them down because there was residential housing within one thousand meters of Ruihai's planned warehouse. But Mr. Yu said, "Not to worry, he would take care of it," and he did.<sup>24</sup> He found another firm whose assessment concluded that the location was suitable for the company's warehouse business.<sup>25</sup>

Delays in obtaining the requisite permits did not preclude Ruihai from commencing their operations.<sup>26</sup> Clients started to store chemicals with the company beginning in February 2014, though Ruihai did not receive temporary permission to do so until May 2014. When that permit expired six months later, they applied for an extension; however, they continued to operate between October 2014 and June 2015 without a license for handling hazardous goods. As Mr. Yu said, “We did not cease operation because we did not think it was a problem. Many other companies have continued working without a license.”<sup>27</sup>

Within two years, Ruihai Logistics with its website’s promise of “outstanding service” had claimed a major share of the hazardous material shipping market in Tianjin: its speed in operation contrasted with its state-run competitors, as did its prices.<sup>28</sup> Friends in the customs department sometimes set up pre-approvals, making it easier to expedite customers’ goods.<sup>29</sup> Ruihai was growing fast; they were storing at least twice the amount of hazardous chemicals than they had licenses for.<sup>30</sup> Even after an expansion, the yard was crowded. Containers had to be stacked in three or four or even five levels instead of the recommended two.<sup>31</sup> There never seemed to be enough time or space to get completely organized and in order. The company was concentrating on speed of service. Managers did not have enough time to conduct safety training for staff.<sup>32</sup> But everything seemed to be under control—they had hired several experienced managers, who had worked with Mr. Yu at Sinochem.<sup>33</sup>

## **Warnings**

A few years before Ruihai began its operations, Professors Shao Chaofeng and Sun Xiaorong at Nankai University’s College of Environmental Science and Engineering in Tianjin had started modeling potential harms associated with the rapid urban and industrial development in the region. In 2010, they published a paper outlining their model’s predictions: a growing danger of an environmental accident, with a high probability of one occurring in 2015, if strong countermeasures were not taken.<sup>34</sup> In a subsequent paper in 2013, they warned specifically of the high danger of chemical-storage-and-transportation-associated incidents in the region. They mapped high-risk zones. One such zone was very near to where Ruihai was then building its warehouses and where it would operate in 2014 and 2015 (see Appendix Figure 1).<sup>35</sup>

## **Part II: August 12, 2015**

### **The Event**

Was there an earthquake? Were they under attack? Did a car explode? Was there a fire? Questions poured into Tianjin’s Emergency Command Center shortly after 11:30 p.m. on the muggy night of Wednesday, August 12.<sup>36</sup>

A little before 11 p.m., a car was reported to be on fire, followed by multiple calls about a fire in the area around Ruihai—most calls came from residents in the apartments with a view over the Ruihai yard (see Figure 1 for a brief timeline). In response, the young

cadets from the fire brigades at the Tianjin Port Public Security Building roared out in their fire engines. Many of them were eighteen or nineteen, just starting a two-year temporary contract.<sup>37</sup> For many, this was their first fire mission; for some, it would be their last. The cadets soon realized that the accident was more serious than a car fire: the contents of a shipping container had caught fire, perhaps through spontaneous combustion. Some responders were unaware that Ruihai had potentially dangerous chemicals on site. The first responders lacked protective gear. Soon other brigades, more experienced, arrived from various departments in Tianjin. But the yard was too crowded for the fire engines to get through, and the responders began ordering cranes to move some of the containers out of the way.<sup>38</sup>

The responders could get no information on what was in the flaming container or in the rest of the warehouses. No one on site seemed to know. Nor did the Tianjin Port Public Security Department. The firefighters needed to cool down the site rapidly, as they saw more and more containers getting engulfed in the flames. The fire kept getting hotter and hotter. A commander gave the order to evacuate and the police and firefighters began helping people escape Ruihai. Reinforcements continued to arrive from elsewhere in the region.

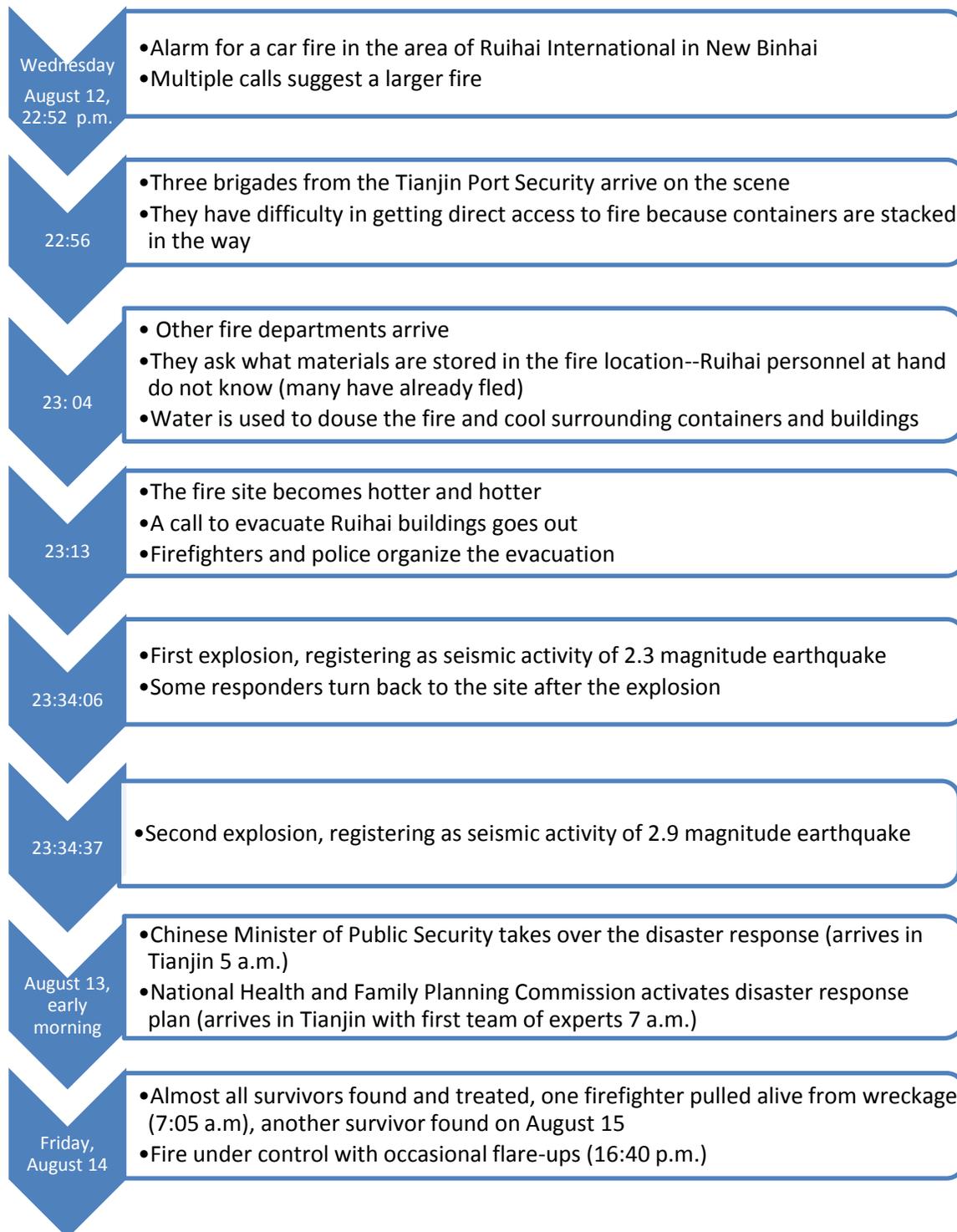
At 11:34 p.m., Zhai Lei, Liu Xiaofu, and Tian Baojian were just getting into their fire truck, when the ground rocked and the truck's windows shattered.<sup>39</sup> Something had exploded, something big. They ducked into the relative safety of the truck. Thirty seconds later, a giant mushroom cloud of fire burst twenty stories high into the night sky, a blast of light, smoke, and sound. Shock waves shook the New Binhai area. Cars and shipping containers flew into the air. Glass cascaded from towers, the warehouse and several other buildings collapsed. Farther from the epicenter, doors blew out of frames, foundations cracked.

What had been a firefighting scene became a scene of carnage that spread far beyond the warehouses. Hundreds were injured, with the firefighters and police at Ruihai hardest hit. Firefighters Zhai and Liu had sheltered in the back of the fire truck; they survived. Firefighter Tien, less protected in the front seat, did not. He was twenty-years old.

Tianjin Port's Public Security Building, headquarters for those first brigades of firefighters, was gone. Quan Li, a firefighter who had been running back to the building, was knocked to the ground by the first blast. He survived because he had not made it back to the building in time for the second blast. His wife, who also worked for the fire department and who was on the fifth floor of the building at the time of the explosion, was not as lucky. She, along with many of her colleagues in the building, perished in the fire.

In a temporary workers' dormitory across the street from Ruihai's city center side, where 2000 workers slept, Su Zhaoqing, a 65-year-old construction worker woke to the crash of debris falling around him. As the building started to collapse, Mr. Su, who was on the lower bunk of his bed, managed to crawl to safety with minor head wounds. Not all were as lucky; some succumbed to their injuries.<sup>40</sup>

**Figure 1: Tianjin Accident Timeline**



Based on Gui Fu, Jianhao Wang, and Mingwei Yan, "Anatomy of Tianjin Port fire and explosion: Process and causes," *Process Safety Progress* 35, no. 3 (2016): 217, Figure 2, supplemented by newspaper accounts.

## Emergency Response

In the immediate aftermath of the explosions, the Tianjin Emergency Center was completely overwhelmed. Not only were they inundated with a very high volume of calls, but they were also struggling to piece together what had actually happened.<sup>41</sup> With the effects of the explosion spread over such a wide area, they were receiving calls from multiple locations with varying descriptions of what had happened. Their inability to perceive what was happening blocked their capacity to craft a cohesive response.

Fire, police, and medical emergency personnel from different areas did not have a unified communication system. Not knowing the exact nature of the accident, first responders were not equipped with the protective gear required to keep them safe from the chemicals they were about to be exposed to. On reaching the site, even after realizing that large chemical containers might be on fire, the responders focused on saving lives and did not stop to survey the scene for toxic chemicals.<sup>42</sup> By the next morning, more than 1000 firemen and soldiers had been mobilized to rescue 60 people, and evacuate 400 more from the explosion site.<sup>43</sup>

Patients were taken to regional hospitals. Those closest by, like Tanggu and TEDA Hospitals, were quickly overwhelmed by large volumes of patients. With limited prior training in responding to mass casualty incidents, community hospitals like Tanggu ended up seeing patients in the order in which they presented, quickly overwhelming their facilities and surgical capacity. The absence of a triage decision process sometimes precluded those needing emergency care from receiving timely attention and resulted in some injured patients being turned away without medical examination.<sup>44</sup>

Tertiary facilities like Pinjijin, closer to the city center, were better equipped to deal with mass casualties. Pinjijin hospital staff noticed that patients arrived in two distinct surges. The first surge, within two hours of the event, was largely comprised of those with lesser acuity, none of whom were brought via ambulance. Only 24 of these first 262 patients at Pinjijin were hospitalized. The second surge, four hours later, brought in 31 new patients, of whom 30 were admitted. These patients had been triaged on site by the Tianjin Emergency Center.<sup>45</sup> (Please see Supplement for additional details).

Immediately after the explosion, Binhai New Area Administration put into force the local emergency response mechanism. It opened ten schools to provide shelter to the more than 3000 residents of the area, along with drinking water, food, and folding cots.<sup>46</sup> Within 40 minutes of the explosion, the Tianjin Health Commission enacted the regional medical emergency plan, which included notifying 29 regional hospitals and the national authorities.<sup>47</sup> Medical emergency headquarters were set up in TEDA Hospital.<sup>48</sup> China's National Health and Family Planning Commission mobilized medical teams from outside Tianjin; by 7 a.m. on August 13, the first team of national medical experts had arrived in Tianjin.<sup>49</sup> Over 100 medical staff from Beijing, including the Deputy Director of the Commission, reported to Tianjin by the afternoon of August 13 to support response and recovery activities.<sup>50</sup> Others soon arrived from Shanghai and Hebei. Tianjin's proximity to Beijing and the highly developed regional transportation network made the port city easily accessible by road and rail. Expert assistance from beyond Tianjin included surgery and burn specialist teams, intensive care unit nurses, and mental health

professionals to support victims. They initially reported in to headquarters at TEDA, where an expert team evaluated the most difficult cases on a daily basis.<sup>51</sup> Several were dispatched to other hospitals. The Commission also ensured that critical supplies, including blood, were available. By the evening of August 13, almost all survivors had been rescued and undergone initial treatment.<sup>52</sup>

Civilians played an important role. Right after the explosion, lay people drove the injured to hospitals and even helped to bind wounds; within three hours, one hospital had received more than 500 blood donors; on Thursday, long lines had formed at city blood stations.<sup>53</sup> Volunteers handed out supplies to evacuees and offered assistance. Hotels opened their doors to those in need.<sup>54</sup> This “unofficial” medical response from Tianjin contributed to the rapidity of the initial local rescue efforts.<sup>55</sup>

Meanwhile, by 3 a.m. on August 13, the Tianjin Environmental Protection Bureau had set up air monitoring equipment downwind from the site. The Bureau noted “high levels of airborne pollutants, including methylbenzene, trichloromethane, and epoxyethane.”<sup>56</sup> The Ministry of the Environment began contacting chemical experts. Guo Shengkun, the Minister of Public Security, took over supervision of response efforts in the early morning hours, arriving in Tianjin by 5 a.m.<sup>57</sup> He mobilized services from across the country, including from the International Atomic Energy Agency’s Beijing environmental emergency response center. It was clear that identifying the chemicals warehoused at Ruihai was an urgent priority in order to enable the rescue teams to proceed safely and securely.

Workers at the warehouse could provide little information. The deputy general manager informed the authorities that the stored chemicals included potassium nitrate, sodium nitrate and nitrate salts—known to be highly explosive especially when exposed to heat. Ruihai’s records were obliterated in the explosion, and elsewhere there was no accurate or current inventory of the stored materials. Ruihai’s website listed six different categories of hazardous chemicals, including calcium carbide, which if it comes in contact with water, creates a highly combustible gas.<sup>58</sup> As it became known that there had probably been calcium carbide on site, firefighters were criticized for using water. Suspicions arose that a water/calcium-carbide interaction might have caused the explosions. Lei Jinde from the firefighting department of the National Public Security Bureau said that firefighters had known there was some calcium carbide on site. However, since no one seemed to know how much or where it was and given that other compounds on site could potentially explode with heat, they wanted to “bring the temperatures down.” Lei said “It wasn’t that firefighting teams were stupid, and used water to fight the fire without [realizing] there was calcium carbide.”<sup>59</sup>

On the afternoon of August 13 excavation for survivors was suspended for a few hours while the site was surveyed for chemicals.<sup>60</sup> The excavation was soon resumed by specialists in protective gear; a young firefighter was found alive on August 14.<sup>61</sup>

For fear of the amount and toxicity of unknown chemicals, the response team decided to pour cement down the drains in the area to keep the chemicals out of the water table and the ports.<sup>62</sup> The decision was a good one. The Hebei Chemical Company came forward saying that it had stored 700 tons of sodium cyanide at Ruihai. Sodium cyanide

interacts with water to form a toxic gas. It can also turn to toxic dust in an explosion. For most of the period after the explosion, the wind was blowing towards the ocean taking any dust away from inhabitants. On August 15 when the wind shifted, the government ordered an evacuation of the area within three kilometers of the blast site until they could test the air quality. Many of those close to the site had already left because of the explosion, but one of the schools which provided shelter for the original evacuees was within the three kilometer zone.<sup>63</sup> The army went building by building to encourage evacuation. By early evening of August 15, the evacuation order had been lifted and people were allowed back.<sup>64</sup>

## **Impact**

A majority of deaths occurred in the immediate aftermath of the accident and were comprised mainly of first responders who were at the site at the time of the explosion. 104 firefighters and 11 police officers perished.<sup>65</sup> As of August 14 at 3 p.m., 58 patients in several different hospitals in Tianjin were classified as critically injured; the medical expert team decided they would be best served if concentrated in four hospitals.<sup>66</sup> Almost all of these survived. For example, Tianjin Medical University General Hospital and Pinjijin Hospital (discussed in Supplement A) recorded only three deaths in the month after the accident, out of 531 patients admitted.<sup>67</sup>

The explosions had severely damaged buildings up to three kilometers away. Buildings up to five and a half kilometers away were also moderately damaged.<sup>68</sup> The explosions resulted in two craters at the site, the largest one hundred meters wide.<sup>69</sup> Two residential high-rises were severely damaged; banks, grocery stores, and other local businesses were destroyed, as well as the goods in and near Ruihai waiting to be shipped overseas. Renault lost more than 1,500 brand new cars to the blaze; Volkswagen had similar losses.<sup>70</sup>

In spite of the large death toll, on August 13 many sections of the vast Tianjin Port reopened for ship traffic (except for the Dongjiang area of the port where the explosion occurred), with a ban on hazardous materials.<sup>71</sup> Within days of the Tianjin disaster, ports across China adopted tighter regulations including refusal to accept unlabeled cargo, denying permission to store hazardous material at the port (requiring immediate ground transport), denying permission to offload certain categories of hazardous material at all, or re-routing certain shipments to other destinations.<sup>72</sup> Figure 2 (on the next page) summarizes direct losses from the accident.

By August 18, after the initial site survey and with 2,000 people searching for and cleaning chemicals from the site, the authorities estimated that there had been 3,000 tons of highly toxic chemicals stored at Ruihai.<sup>73</sup> The rescue team had enlisted more than one hundred people from various chemical companies to provide advice.

Figure 2 Direct Losses from the Tianjin Accident

|   |  |
|---|--|
| <b>Deaths (includes 8 missing, presumed dead)</b> | 173  |
| <b>People Receiving Emergency Treatment</b>       | 3,000  |
| <b>People Hospitalized</b>                        | 798  |
| <b>Destroyed Buildings</b>                        | 304  |
| <b>Destroyed Vehicles</b>                         | 12,428   |
| <b>Residents with Damaged Homes</b>               | 17,000   |
| <b>Total Verified Direct Economic Loss</b>        | 6.866 billion<br>Chinese yuan<br>(approx. \$1.1 billion<br>US) |

Based on Gui Fu, Jianhao Wang, and Mingwei Yan, “Anatomy of Tianjin Port fire and explosion: Process and causes,” *Process Safety Progress* 35, no. 3 (2016): 217, Table 1, with some additions.

Intensive remedial work began almost right away in the form of various construction projects, including building a meter-high embankment around the center of the site to prevent water leakage, digging a 20,000 square meter nonporous trench for containing the contaminated soil, and erecting a temporary cyanide treatment facility.<sup>74</sup> Since the morning after the blast, the Tianjin Environmental Protection Bureau has regularly monitored both air and water quality and released its findings publicly. According to an article in the *Chinese Journal of Emergency Medicine*, water testing results reached national standards within six weeks of the accident.<sup>75</sup> However, as of July 2016, apartment buildings near the blast still had two sets of signs, “No cyanide found” and “Don’t drink the tap water.”<sup>76</sup> On August 17 the Bureau reported that sodium cyanide had been found at 17 sites, with areas closest to the explosion having readings four times the permitted level. The Ministry of Environmental Protection alerted monitoring stations in nearby provinces and cities to also watch for airborne pollutants.<sup>77</sup> By September 4, 2015, air quality indicators for Tianjin were reported to be within normal range.<sup>78</sup>

These contradictory messages reflect the ongoing uncertainty as to the extent of contamination and its long-term effects—and perhaps also the anxieties and mistrust entailed in living next to a hazardous waste clean-up site. Despite the massive resources used in remedial work mentioned above, site rectification has taken longer than hoped. Binhai district government had expected to open a park at the site with a memorial to the firefighters by the one-year anniversary of the disaster, but contaminated water and soil delayed construction of the memorial. Soil closer to the apartment buildings was dug up and replaced.<sup>79</sup> Pollution monitoring continued, as did monitoring of health effects from exposure to the blast and the subsequent pollution. However, many citizens lacked information about the testing they should undergo.<sup>80</sup> As of May 2016, no deaths had been attributed to poisoning or environmental pollution from the accident.<sup>81</sup>

### **Part III: Investigation Report, February 2016**

The extensive investigation conducted by the government was completed more than five months after the accident. The report, released in early February 2016, found that Ruihai had “severely violated” requisite safety regulations and practices, including national standards on residential risk appraisal, standards on production safety, and regulations for hazardous chemicals (see Figure 3).<sup>82</sup> It also concluded that a majority of relevant regulatory authorities had failed to execute their responsibilities.

The government investigation stated that the explosions resulted largely from compromised safety standards, gross lack of oversight, and an overall lack of accountability in both the public and private sectors.

#### **Gross Violations of Safety Standards**

The report identified the initial cause of the fire as spontaneous combustion of nitrocellulose, due to improper handling.<sup>83</sup> Nitrocellulose, also known as flash paper or gun cotton, is a combustible chemical that must stay moist for chemical stability and safe storage, and is to be packed in wetting agents such as ethanol or water. If allowed to dry, the chemical can self-ignite. The nitrocellulose at Ruihai was packaged in plastic bags with a wetting agent, but without a thermoplastic seal. Warehouse operators (who had not received safety training) had inadvertently damaged the packages while handling them, which allowed the wetting agent to evaporate and some nitrocellulose to be spilled in the surrounding storage area. The temperature on August 12 reached 36 degrees Celsius, with temperatures in the warehouse reaching 65 degrees Celsius. As the residual wetting agent evaporated, and the temperature in the closed containers rose, the nitrocellulose burst into flames, quickly spreading to the adjacent containers—all packed with highly inflammable or toxic materials including nitrates, sodium sulfide, alcohol, trichlorosilane, methyl trichlorosilane, and formic acid.

Experts agreed that the two subsequent explosions had not been caused by water interacting with carbide or metallic powder, but by ammonium nitrate, which is highly inflammable and explosive at high temperatures. There were 800 tons of ammonium nitrate stored at Ruihai.<sup>84</sup> The initial fire had reached 400 degrees Celsius, causing the ammonium nitrate in containers nearby to explode. Approximately 20 meters northwest from the first explosion, the flames reached another set of containers of ammonium nitrate, resulting in the second explosion. (See Appendix Figure 2 for the comparative role of ammonium nitrate in other large-scale industrial explosions).

According to the report, Ruihai had grossly flouted safety regulations, storing many times the amount of chemicals permitted on site (see Appendix Figure 3). Ruihai also had neglected to report the location and the amounts of various hazardous material to fire safety personnel, nor had it ensured that workers on site had knowledge of the properties of chemicals they handled. Even worse, Ruihai had not isolated different types of chemicals from each other, creating a highly complex technical challenge for the firefighters. Chemicals like calcium carbide are combustible when they come in contact with water, while fires from nitrates are best quenched with water. The deputy director of the fire department at the national level said that it was the most complex disaster he had seen in 40 years.<sup>85</sup>

**Figure 3 Ruihai’s Wrongdoings, according to the State Investigation (13 People from Ruihai Charged)**

| Wrongdoing  | Examples  |
|---|---|
| 1. Serious violations of New Binhai Area Planning Regulations                     | Initial warehouse should never have been built. Ignored rules.  |
| 2. Illegal business, without appropriate documents                                | Operated without valid Port License or Hazardous Goods Certificate for several months.  |
| 3. Improper means to obtain management approval of dangerous goods business       | Ruihai gave gift certificates, golf games, and wined and dined members of the Tianjin Transport. Commission. Ruihai used Mr. Dong’s father’s influence as police chief to gain Port approvals.                                |
| 4. Illegal storage of ammonium nitrate  |   |
| 5. Seriously overloaded operation, excess amount in storage                       | Ruihai was carrying many times the amount of hazardous goods that it had been licensed for.   |
| 6. Commingling of categories of dangerous goods, high stacking of dangerous goods | Did not isolate different categories of dangerous goods in different zones.   |
| 7. Illegal conduct of unpacking, handling, loading and unloading operations       | Rough handling of dangerous goods by workers; no monitoring; general lack of safety management.   |
| 8. Failure to register major hazards  | Did not report amount, storage location, etc. of dangerous chemicals to safety authorities—i.e. Port Public Security Bureau, etc.   |
| 9. Lack of production safety education and training                               | Workers’ knowledge of site management risk protection generally consisted of “no smoking allowed.”  |
| 10. Failure to develop contingency plans and organize drills                      | No emergency response plan, no regular emergency drills. Did not notify neighbors (including nearby residential communities, businesses, or local hospitals in emergency response requirements to onsite chemical exposures). |

Source: Compiled from State Council investigation team, *Accident investigation report of explosion accident in Tianjin Port on August 12, 2015*, [in Chinese] February 2016, on State Administration of Work Safety website, <http://www.chinasafety.gov.cn/>, 20-32; see also in English, Gui Fu, Jianhao Wang, and Mingwei Yan, “Anatomy of Tianjin Port fire and explosion: Process and causes,” *Process Safety Progress* 35, no. 3 (2016): 216-220.

The lack of stipulated space around the closely packed containers (stacked on top of each other) precluded easy access to the rescue vehicles—causing severe delays as fire brigades waited for cranes to arrive and move the containers out of the way. Without this half-hour delay, the explosion might well have been avoided, according to an article in *Process Safety Progress*.<sup>86</sup>

## **Residential and Industrial Planning**

The explosions and aftermath not only raised critical questions about the safety of chemical management and storage but also raised issues around the siting of hazardous chemical sites near residences. Ruihai's warehouses were located within three kilometers from dense residential communities, including multiple dormitories for migrant workers within a few hundred meters. Two major highways and a railway station were located within 800 meters from the facility—all in violation of national law, as the State Council report noted and condemned.

However, other reports pointed out that the law was not generally enforced and that it did not specifically forbid locating hazardous sites near residences, but rather near public buildings and major transportation routes.<sup>87</sup> A *New York Times* article cited a 2010 Ministry of Environmental Protection survey in which half of China's oil processing and chemical plants were less than a mile from schools and residential areas.<sup>88</sup> An investigative team with *China Youth Daily* reporting in October 2015 found that the standard of a thousand meters was rarely applied and that later (less stringent) guidelines had made existing standards even more ambiguous by dividing requirements into an A list (mandatory) and a B list (desirable).<sup>89</sup> The thousand-meter requirement was placed on the B list, allowing companies to receive permits when they were within the thousand-meter zone if they met all criteria on the A list. Also the description of the safety zone was changed to include dangerous facilities within the thousand meters, if they were "taking measures to ensure safety."<sup>90</sup> The team reported that most officials whom they had interviewed agreed "that local land shortages meant the 1,000 [meter] requirement was not taken seriously, and that the limit itself had always been controversial."<sup>91</sup>

In 2014, China had strengthened its Environmental Protection Law by requiring companies to publicly disclose information about on-site chemicals including the type, quantity, and concentration. Yet according to the investigation, not only was this information withheld, Ruihai and its contractors had not followed required processes for holding public hearings and conducting environmental impact assessments (EIA).<sup>92</sup> A company that had conducted the EIA for Ruihai claimed that it had received 128 responses (out of 130) in favor of the warehouse in surveys administered at nearby apartments. But neither those living in the apartment complex nor the developer remember getting such surveys.<sup>93</sup> The company had misreported the distances from residential and public use buildings and concluded that Ruihai was in compliance.<sup>94</sup>

## **Negligence and Lack of Oversight**

The investigation was unequivocal in its assessment of lapses in governance and accountability. The sub-optimal (and outright dangerous) storage measures and non-compliance with safety and zoning laws should have been investigated and regulated

by the relevant government authorities.<sup>95</sup> The investigation observed that “relevant local Communist Party committees and government departments displayed problems including failure to abide laws, lax enforcement, lack of supervision and negligence.”<sup>96</sup>

According to the investigation report, Ruihai had begun warehousing chemicals in 2014, four months prior to receiving a temporary permit from the Tianjin Transport Commission, which should never have granted them such a permit; the Commission then failed to supervise Ruihai’s business activities.<sup>97</sup> Additionally, Wang Jinwen, the deputy director of the Waterway Transportation Authority illegally exercised power to help Ruihai pass the safety assessment.<sup>98</sup> The Binhai District Plan and Land Resources Administration, in particular, knew that the company was handling dangerous chemicals and that the storage locations did not meet zoning standards. Yet it failed to investigate the matter or deny Ruihai operating approvals. Similarly, the Tianjin Administration of Work Safety and the New Binhai Administration of Work Safety, both responsible for reviewing protocols and processes as well as identifying potential safety hazards, failed to identify any potential hazards.

The official report noted that negligence, corruption, or fraud were found at multiple levels and across agencies, including within the Ministry of Transport, the management at Tianjin Port, different bureaus in the Tianjin municipal government, and local district authorities of Binhai New Area. Agencies that carried out safety assessments, drew the plans for the warehouses, and conducted the Environmental Impact Assessment were also found negligent. (See Appendix Figure 4, for a list of organizations beyond Ruihai found negligent).

### **Responder Preparedness**

The investigation stated that Ruihai had failed to inform the surrounding communities and relevant government agencies of the quantity and nature of the hazardous cargo stored on site, though the Environmental Protection Law required it do so.<sup>99</sup> Not noted by the State Council investigation was the widespread non-compliance to reporting requirements by companies and government entities beyond Tianjin.<sup>100</sup> For example, an independent group that surveyed 31 provinces to assess government transparency around dangerous chemicals found only one province, Zhejiang, to be compliant.<sup>101</sup> Most provinces (25) refused to provide information to their communities on hazardous chemical sites because of fears about security and terrorism. This culture of non-compliance and lack of information about the nature of hazardous goods at industrial sites severely compromised the safety of first responders, exposing them to unnecessary and unknown risks. It also precluded them from formulating an effective, targeted, and planned response strategy.

Chemical product companies are required to provide warehouse operators a material safety data sheet (MSDS), listing the names and quantities of chemicals transported. The majority of filed MSDS in China are said to be useless due to falsified data which could then provide inaccurate information to emergency responders.<sup>102</sup>

The report noted that the fire department of the Tianjin Port Public Security failed to insist that Ruihai provide this information, and had failed to train their firefighters in the

proper methods of combatting chemical fires. The medical responders and receiving hospitals were equally unaware of the nature of toxic materials stored at the port.

### **Remediation and Penalties**

On August 14, two days after the blast, the government ordered nationwide inspections of hazardous chemicals and explosive materials.<sup>103</sup> The results of those inspections were almost immediate: by the end of September 2015, more than 10,000 enterprises suspended production while they took measures to come into compliance; 2,500 were banned or shut down; and more than 900 people were under criminal investigation. The number of large accidents dropped by 40 percent and related fatalities by more than 27 percent compared to the same month in 2014.<sup>104</sup>

Reaction to the accident speeded up plans to relocate some potentially dangerous companies; by August 30, local governments across China had submitted plans to relocate or upgrade almost one thousand chemical plants, which the Ministry of Industry had been requesting for more than a year.<sup>105</sup> The government also created new requirements for information technology linkages between chemical companies and public safety organizations.

The government continued its emphasis on safety in hazardous industries into 2016, but with mixed results and with some signs that the focus on safety had become diffused to avoid interfering with industry growth.<sup>106</sup> In July, the Ministry of Environmental Protection lifted the regulation requiring public notification of chemicals—of which the investigation had emphasized Ruihai's non-compliance.<sup>107</sup> China still has a major problem with chemical risk management: from January through August 2016, there have been 232 chemical accidents.<sup>108</sup>

However, the survey operation did shut down some potentially harmful operations as illustrated above and in its investigation of the Binhai New Area. In the Binhai New Area, the district administration identified 583 companies working with chemicals, of which 85 were closed or relocated after safety checks. The 583 included three fireworks warehouses, 100 companies transporting hazardous material, and 61 companies handling hazardous cargo on the port. The authorities adopted advanced GIS (geographical information system) technology to map chemical sites in the area and share information with emergency command systems. As of January 2016, the program monitored 309 companies, and was expected to reach 379 by the end of the year.<sup>109</sup>

Other safety improvement effects and efforts continue. In December 2015, the People's Supreme Court clarified issues of personal accountability and related penalties for company and official malfeasance relevant to the Ruihai case.<sup>110</sup> In May 2016, several ministries jointly announced a program on safe storage of hazardous chemicals, with May through July for information dissemination and company self-inspection, August through October for intensive law enforcement inspections, and November for a review and report to the State Council.<sup>111</sup> In December 2016, the State Council announced a three-year plan to review the handling of dangerous chemicals, including further nationwide inspections, clarification of regulatory responsibility, and increased accountability.<sup>112</sup> The review is to result in a risk distribution map by March 2018,

creating dedicated industrial zones for chemicals and closure or relocation of facilities located near residential areas.<sup>113</sup> As the program is to include funding for those facilities, it may be similar to the July 2016 plan for the city of Beijing, with cash offered to hazardous chemical plants that leave the city, with hopes of 60 departures by the end of 2016 and an additional 20 by the end of 2018.<sup>114</sup>

The State Council investigative report recommended action against 123 people, including five officials at the ministerial level. The report suggested that 74 officials be disciplined by the Communist Party. In addition, 49 people (including Ruihai's founders, Dong Shexuan and Yu Xuewei) were arrested on charges ranging from dereliction of duty to fraud.<sup>115</sup> In November 2016, Yu Xuewei received the most serious punishment: he was sentenced to death, with the sentence suspended for two years (and likely then commuted to life). Others received jail sentences ranging from one year to life.<sup>116</sup>

## **Part IV: Discussion**

This disaster reminded Wang Jie of many she had studied in her career.

The lack of situational awareness, the lack of critical information about the chemicals, and the lack of rigorous safety training had precluded workers at the Union Carbide factory in Bhopal in India from responding quickly to a suspected gas leak.<sup>117</sup> The leak, unchecked, escaped into the surrounding countryside resulting in a large number of deaths (estimated range from 3500 to 15,000 deaths and 500,000 injuries of varying severity).<sup>118</sup> Medical personnel responding to the disaster had no information about the nature of the chemicals that had escaped the factory.

The explosions at Tianjin also bore similarity to the West Fertilizer Company explosion in Texas, where gaps in jurisdictional oversight had allowed the unregulated and unsafe storage of ammonium nitrate fertilizer.<sup>119</sup> A subsequent fire resulted in a massive explosion caused by the ammonium nitrate. The death toll, as in Tianjin, included emergency responders, employees, and civilians. 15 people died, and over 150 homes were destroyed.

As she looked at the recommendations for the report, Wang Jie was in deep thought. Were these enough? What steps should the government take to avoid another disaster like this? What should she focus on? Was more regulation needed? Or simply better enforcement? A different supervisory structure?

Among the dead were 104 firefighters—the largest loss of firefighters on duty in the history of the Peoples Republic of China since its founding in 1949. What could Wang Jie do to make it safer for emergency responders to respond to such disasters? What kind of information and training should communities and officials around these industrial sites have? How should this information be kept up to date and disseminated? What role can communities play in such monitoring? What other responders need to be better informed?

# APPENDIX

1. Figure 1 Map of New Binhai Area with environmental risk in January 2013
2. Figure 2 The Danger of Ammonium Nitrate
3. Figure 3 Hazardous Chemicals at Ruihai, Amount Permitted Vs. Amount Present.
4. Figure 4 Organizations Other than Ruihai Found at Fault in the Tianjin Accident

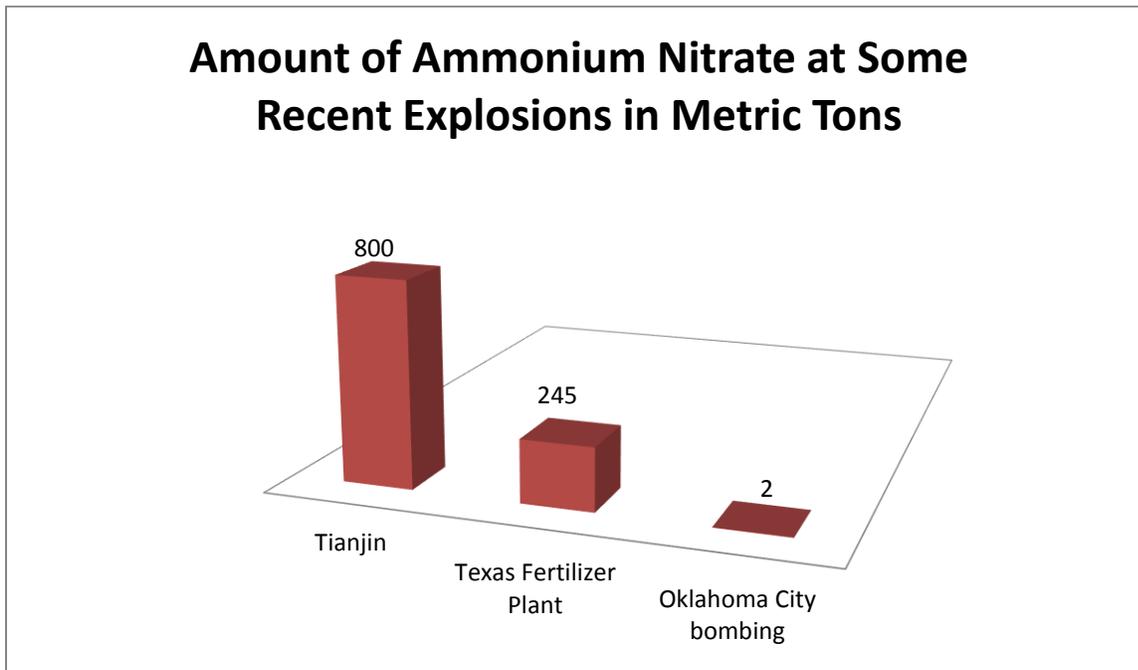
**Appendix Figure 1 Map of New Binhai Area with environmental risk in Jan 2013**



|   |   |   |
|---|---|---|
|  Residential land                |  Port and airport land | 1-7: The areas with a large number of environmental risk sources at present.<br>8: The area was planned in the future according to the result of environmental risk assessment, which will introduce the enterprises with risk sources. |
|  Public facilities land          |  Tourism land-use      |   |
|  Industrial land                 |  Urban park land       |   |
|  Warehouse land                  |  Country park land     |   |
|  Municipal utilities land        |  Green land            |   |
|  Land for the future development |  Marine salina         |   |
|  Rural construction land         |  Water area            |   |
|   |   |   |

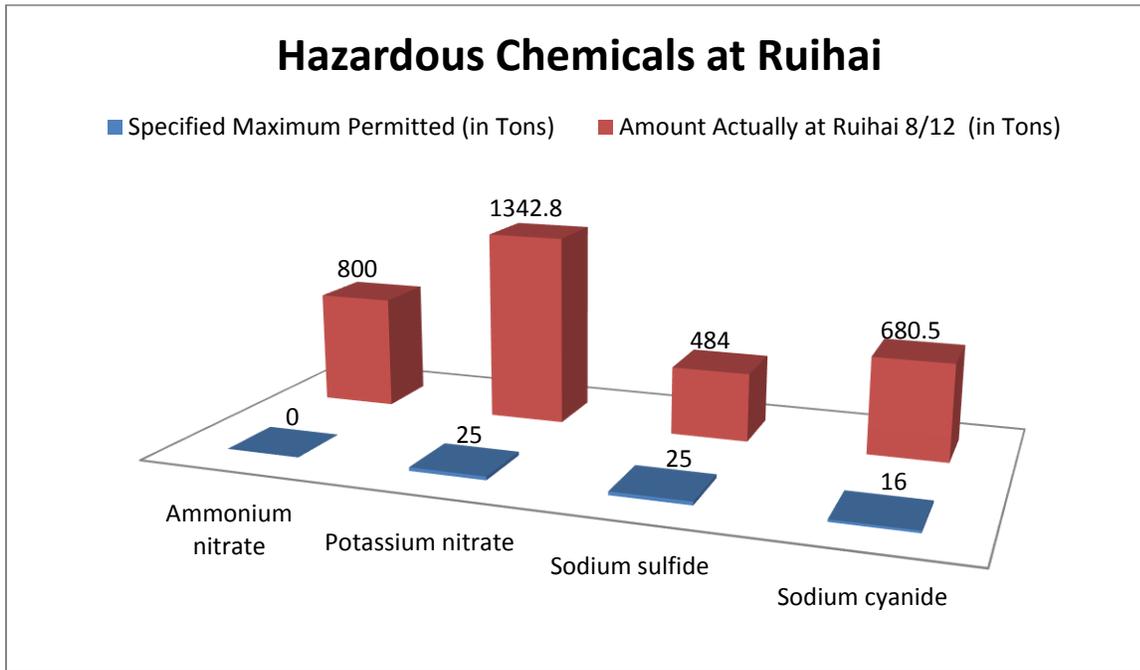
Note: The Tianjin explosion took place on warehouse land (colored purple) above area 3 in this map, to the left of the small peninsula. In January 2013, neither Ruihai logistics or the new housing developments had opened. Source: Chaofeng Shao, Juan Yang, Xiaogang Tian, Meiting Ju, and Lei Huang, "Integrated Environmental Risk Assessment and Whole-Process Management System in Chemical Industry Parks," *International Journal of Environmental Research and Public Health* 2013 10: 1619, Figure 5, doi:10.3390/ijerph10041609, Permission through Creative Commons license, (<http://creativecommons.org/licenses/by/3.0/>)

## Appendix Figure 2 The Danger of Ammonium Nitrate



Source: Data: Tianjin, from Gui Fu, Wang Jianhao, and Mingwei Yan, "Anatomy of Tianjin Port fire and explosion: Process and causes," *Process Safety Progress* 35, no. 3 (2016), 217-218; Texas, Ralph Vartabedian, Neela Banerjee, and Ricardo Lopez, "Chemical in Texas blast has a well-known deadly potential," *Los Angeles Times*, April 18, 2013; Oklahoma City: US Federal Bureau of Investigation (FBI), "The Oklahoma City Bombing Twenty Years Later" FBI 2015, <https://stories.fbi.gov/oklahoma-bombing/>.

**Appendix Figure 3**  
**Hazardous Chemicals at Ruihai, Amount Permitted Vs. Amount Present**



Source: Data from Gui Fu, Wang Jianhao, and Mingwei Yan, "Anatomy of Tianjin Port fire and explosion: Process and causes," *Process Safety Progress* 35, no. 3 (2016), 217-218.

**Appendix Figure 4**  
**Organizations Other than Ruihai Found at Fault in the Tianjin Accident**

| Organizations Found at Fault at Different Levels of Supervision and Operation |   |  |  |  |
|---|---|--|--|--|
| Ministry and National Govt  | Tianjin Port-Related                              | Tianjin City                                     | Binhai New Area District (BNA)                 | Local Units, Independent Groups                          |
|   |   | Tianjin Party Committee                          | BNA Party Committee                            |  |
|   |   | Tianjin Municipal Government                     | BNA Government                                 |  |
| Ministry of Transport   | Tianjin Port Group                                | Tianjin Transportation Commission                | BNA Planning and Land Resources Administration |  |
|   | Tianjin Port Construction Co                      | Tianjin Work Safety Administration               | BNA Work Safety Administration                 | Tianjin Binhai Sheng Weisheng Safety Evaluation Co., Ltd |
|   | Tianjin Port Public Security Bureau, Fire Brigade | Tianjin Public Security Bureau                   | BNA Public Security Bureau                     | Chemical Design Institute in Tianjin                     |
|   | Tianjin Maritime Bureau                           | Tianjin Quality and Technical Supervision Bureau | BNA Quality and Technical Supervision Bureau   | Tianjin Institute of Architectural Design                |
| General Customs Administration  | Tianjin Customs                                   |  | BNA Environmental Protection Agency            | Tianjin Environmental Engineering Assessment Center      |
|   |   |  | BNA Admin. Examination and Approval Authority  | Tianjin Bovee Yongcheng Technology Co., Ltd              |

Source: Compiled from State Council investigation team, *Accident investigation report of explosion accident in Tianjin Port on August 12, 2015*, 32-50.

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<sup>1</sup> Yang Ziman, Zhang Min, and Wang Yui, "Industrial transformation continues apace," *China Daily*, May 28, 2016.

<sup>2</sup> Summer Davos 2014 website, Administrative Division, subheading, "Functions of New Binhai Area." *China Daily*, April 15, 2013, [http://www.chinadaily.com.cn/regional/2013-04/15/content\\_17526084.htm](http://www.chinadaily.com.cn/regional/2013-04/15/content_17526084.htm);

<sup>3</sup> Summer Davos 2016 website, "'Tianjin Binhai New Area tour.'"

<sup>4</sup> Li Fusheng and Fu Chao, "Growing fast and going global," *China Daily*, September 9, 2014, [http://www.chinadaily.com.cn/regional/2014-09/10/content\\_18571911.htm](http://www.chinadaily.com.cn/regional/2014-09/10/content_18571911.htm), on Summer Davos 2014 website.

<sup>5</sup> Ms. Wang Jie is a fictional character, but the Chinese State Administration of Work Safety and all the other organization and people named in this case study are real. Sources for this section: Andrew Jacobs, "Death toll in Chinese fire rises, along with anger at apparent safety lapses," *New York Times*, August 14, 2015; People's Daily, "Tianjin Explosions: Chinese authorities to conduct indepth investigation, police arrests," August 19, 2015; Associated Press, "China's head of industrial safety under investigation after Tianjin port blasts," August 18, 2015, found on the *Chicago Tribune* website; People's Republic of China English website, "State Council Organization Chart," updated August 28, 2014, [http://english.gov.cn/state\\_council/2014/09/03/content\\_281474985533579.htm](http://english.gov.cn/state_council/2014/09/03/content_281474985533579.htm); State Administration of Work Safety website [in Chinese only], updated September 22, 2015, <http://www.chinasafety.gov.cn/newpage/>; Andrew Jacobs, "In Tianjin blasts, a heavy toll for unsuspecting firefighters," *New York Times*, August 17, 2015.

<sup>6</sup> Xu Wei, "'Nobody told us there were chemicals here,'" *China Daily*, August 17, 2015, [http://www.chinadaily.com.cn/china/2015tianjinblasts/2015-08/17/content\\_21616941\\_2.htm](http://www.chinadaily.com.cn/china/2015tianjinblasts/2015-08/17/content_21616941_2.htm).

<sup>7</sup> "Modern," "Charming," "Historic" Summer Davos 2014 website home page, <http://www.chinadaily.com.cn/regional/davos2014.html>; "Gateway," Summer Davos 2014 website, "Brief introduction," *China Daily*, December 5, 2012, [http://www.chinadaily.com.cn/m/tianjin2012/2012-12/05/content\\_16056845.htm](http://www.chinadaily.com.cn/m/tianjin2012/2012-12/05/content_16056845.htm); "Glamorous," Summer Davos 2016 website home page, <http://www.tj-summerdavos.cn/2016/english/index.shtml>.

<sup>8</sup> "Five times," Summer Davos 2016 website home page; "Olympic matches," Summer Davos 2014 website, "Brief introduction," *China Daily*, December 5, 2012, [http://www.chinadaily.com.cn/m/tianjin2012/2012-12/05/content\\_16056845.htm](http://www.chinadaily.com.cn/m/tianjin2012/2012-12/05/content_16056845.htm); 2003 figures: 10 million, 2015: 15 million according to Chinese National Bureau of Statistics, *China Statistical Yearbook 2015*, Beijing: China Statistic Press, 2015, "Table 2.5 Population by Region at Year End," <http://www.stats.gov.cn/tjsj/ndsj/2015/indexeh.htm>.

<sup>9</sup> Zhang Chun and Feng Hao, "Jing-Jin-Ji will likely miss 2030 clean air targets," *China Dialogue*, March 30, 2016.

<sup>10</sup> Summer Davos 2016 website, "City Planning and Construction," Enorth.com.cn, November 25, 2015, <http://www.tj-summerdavos.cn/system/2015/11/24/030651904.shtml>.

<sup>11</sup> Yang Feiyue, "Tianjin, a city of taste and joy," *China Daily*, Updated July 16, 2013, on the Summer Davos 2014 website, [http://www.chinadaily.com.cn/regional/2013-07/16/content\\_17526508.htm](http://www.chinadaily.com.cn/regional/2013-07/16/content_17526508.htm), Klaus Schwab quote on 2.

<sup>12</sup> Andrew Jacobs, Javier C. Hernández, and Chris Buckley, "Behind deadly Tianjin blast, shortcuts and lax rules," *New York Times* online, August 30, 2015.

<sup>13</sup> Summer Davos 2016 website, "Administrative Division," Enorth.com.cn, June 21, 2016, <http://www.tj-summerdavos.cn/system/2016/06/21/031029106.shtml>.

<sup>14</sup> See Tianjin Eco-city website, <http://www.tianjinecocity.gov.sg/>.

<sup>15</sup> Summer Davos 2014 website, "Tianjin Binhai New Area," *China Daily*, March 22, 2012, [http://www.chinadaily.com.cn/m/tianjin2012/2012-03/22/content\\_16056837.htm](http://www.chinadaily.com.cn/m/tianjin2012/2012-03/22/content_16056837.htm); Zhou Li, "The Development of Tianjin Binhai New Area and Free Trade Zone," Speech, December 2008, Administrative Committee of Tianjin Port Free Trade Zone.

<sup>16</sup> Summer Davos 2016 website, "With clear orientation and breakthroughs, the Free Innovation Zone delivered 'one-two punch,'" Enorth.com.cn, November 30, 2015, <http://www.tj->

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[summerdavos.cn/system/2015/11/30/030661259.shtml](http://summerdavos.cn/system/2015/11/30/030661259.shtml), Tom Phillips, “Largest animal cloning factory can save species, says Chinese founder,” *The Guardian*, November 24, 2015, <https://www.theguardian.com/world/2015/nov/24/worlds-largest-animal-cloning-factory-can-save-species-says-chinese-founder>.

<sup>17</sup> “Tenth largest,” in Kenneth Rapoza, “The World’s 10 Busiest Ports,” *Forbes* online, November 11, 2014, <http://www.forbes.com/sites/kenrapoza/2014/11/11/the-worlds-10-busiest-ports/#2a0d2cbc53ba>; other data in this paragraph, from the Tianjin Port Group website, particularly from “Overview,” *China Daily*, March 25, 2013, [http://www.chinadaily.com.cn/m/tianjinport/2013-03/25/content\\_16342899.htm](http://www.chinadaily.com.cn/m/tianjinport/2013-03/25/content_16342899.htm) and “International Connections.”

<sup>18</sup> Summer Davos 2014 website, “Tianjin Binhai New Area”; Tianjin Port Group website, “Overview,” p.2, *China Daily*, March 25, 2013, [http://www.chinadaily.com.cn/m/tianjinport/2013-03/25/content\\_16342899.htm](http://www.chinadaily.com.cn/m/tianjinport/2013-03/25/content_16342899.htm); Summer Davos 2016 website, “Sailing into future: Tianjin Binhai New Area,” Enorth.com.cn, June 2, 2016, <http://www.tj-summerdavos.cn/system/2016/06/28/031040958.shtml>.

<sup>19</sup> Summer Davos 2014 website, “Economic Overview,” *China Daily*, March 23, 2012, [http://www.chinadaily.com.cn/m/tianjin2012/2012-03/23/content\\_16056838.htm](http://www.chinadaily.com.cn/m/tianjin2012/2012-03/23/content_16056838.htm).

<sup>20</sup> Sources for this section: Jacobs, Hernández, and Buckley, “Behind deadly Tianjin blast”; Huaxia, ed., “Exclusive: Doubts cast over legitimacy of Tianjin blast warehouse,” *Xinhua*, August 19, 2015, [http://news.xinhuanet.com/english/2015-08/19/c\\_134533871.htm](http://news.xinhuanet.com/english/2015-08/19/c_134533871.htm); State Council investigation team, *Accident investigation report of explosion accident in Tianjin Port on August 12, 2015*, on State Administration of Work Safety website, February 2016, in Chinese only, <http://www.chinasafety.gov.cn/>. Note that Dong’s and Yu’s thoughts are FXB speculation, based on indicators in these sources.

<sup>21</sup> Information about ownership from Huaxia, “Doubts over legitimacy of warehouse.”

<sup>22</sup> Paragraph source: Huaxia, “Doubts over legitimacy of warehouse.”

<sup>23</sup> *Ibid.*, quoting Zhu Liming, deputy head of the bureau, later arrested for his involvement with Ruihai.

<sup>24</sup> Mr. Dong quoting Mr. Yu as reported in Bao Zhiming, Huang Kaixi, Zhao Fuduo, Wang Heyan, Wang Xinci, Zhou Qijun, Wang Su, Zhou Dongxu, Cui Zheng, Qiu Jiaqiu, and Shan Yuxiao, “Tianjin Blast Probe Too Late for Firefighters,” *Caixin* Online, August 27, 2015, <http://english.caixin.com/2015-08-27/100843795.html>.

<sup>25</sup> Tu Chonghang, “Danger next door,” *China Dialogue*, <https://www.chinadialogue.net/article/show/single/en/8955-Danger-next-door>, May 30, 2016 in English, original in Chinese in *Beijing Daily*, August 18, 2015.

<sup>26</sup> Permits: see State Council investigation team, *Accident investigation report of explosion accident in Tianjin Port on August 12, 2015*, 24-26.

<sup>27</sup> As quoted in Huaxia, “Doubts over legitimacy of warehouse.”

<sup>28</sup> Jacobs, Hernández, and Buckley, “Behind deadly Tianjin blast,” including their quote from Ruihai’s website; see also Xue Lei, “Ruihai company cargo storage dangerous chemicals 3,000 tons,” *Beijing Youth Daily*, August 18, 2015, [http://news.ifeng.com/a/20150818/44451149\\_0.shtml](http://news.ifeng.com/a/20150818/44451149_0.shtml).

<sup>29</sup> State Council investigation team, *Accident investigation report of explosion accident in Tianjin Port*, page 37-38, 62.

<sup>30</sup> Gui Fu, Jianhao Wang, and Mingwei Yan, “Anatomy of Tianjin Port fire and explosion: Process and causes,” *Process Safety Progress* 35, no. 3 (2016): 216-220, stacked containers: 217-218.

<sup>31</sup> *Ibid.*

<sup>32</sup> B. Zhao, “Facts and lessons related to the explosion accident in Tianjin Port, China,” *Nat Hazards* (2016) 84: 711-712, doi:10.1007/s11069-016-2403-0.

<sup>33</sup> Huaxia, “Doubts over legitimacy of warehouse.”

<sup>34</sup> Sun Xiaorong and Shao Chaofeng, “Environmental Risk Trends in Tianjin Binhai New Area, Based on the Driving Force, Pressure, State, Impact, Response (DPSIR) Model,” [in Chinese, FXB translation with Google Translate] *Environmental Sciences Research*, January 2010,

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doi:10.13198/j.res.2010.01.70.sunxr.011; also based on English summary in Jacobs, Hernández, and Buckley, “Behind deadly Tianjin blast.”

<sup>35</sup> Chaofeng Shao, Juan Yang, Xiaogang Tian, Meiting Ju, and Lei Huang, “Integrated Environmental Risk Assessment and Whole-Process Management System in Chemical Industry Parks,” *International Journal of Environmental Research and Public Health* 201 10 (2013): 1609-1630, doi:10.3390/ijerph10041609; note that Ruihai had just been founded but was not operational at the time of this paper (original submission January 2013, revised and published April 2013).

<sup>36</sup> Unless otherwise noted, sources for this section are State Council investigation team, *Accident investigation report of explosion accident in Tianjin Port*; Bao Zhiming et al., “Tianjin Blast Probe Too Late.”

<sup>37</sup> Jacobs, “In Tianjin blasts, a heavy toll for unsuspecting firefighters.”

<sup>38</sup> Cranes: Gui Fu et al., “Anatomy of Tianjin Port fire and explosion,” 218.

<sup>39</sup> Firefighters’ story from Bao Zhiming et al., “Tianjin Blast Probe Too Late.”

<sup>40</sup> Andrew Jacobs, “Tianjin, a port in China, is rocked by explosions that killed dozens,” *New York Times*, August 12, 2015.

<sup>41</sup> Chai Yanfen, Shou Song-Tao, Me Ying, and Lu Bin, “8.12 Experience and Reflection on Tianjin Port Hazardous Chemicals Medical Rescue After Explosion,” [in Chinese] *Chinese Journal of Emergency Medicine* 24, no. 10 (2015): 1065-1069, doi:10.3760/cma.j.issn.1671-0282.2015.10.002.

<sup>42</sup> Cui Meng Meng, Fan Da, and Zhang Jinjun, “Lessons Learned from the 8.12 Explosion in Tianjin Port and Its Implications,” [in Chinese] *Chinese Journal of Emergency Medicine* 24, no. 10 (2015): 1078-1081, doi:10.3760/cma.j.issn1671-0282.2015.10.005.

<sup>43</sup> Ma Bo, Mizhe, Meng Xing, Wei Yu, and Zhang Yan, “The first press conference on the explosion accident in Tianjin informed the rescue and disposal situation,” [in Chinese] *Tianjin Daily*, August 14, 2016.

<sup>44</sup> See Michael Woodhead, “China sends in medical teams to cope with casualties of Tianjin blast,” *British Medical Journal* 351(2015): h4475, doi:10.1136/bmj.h4475. Note that TEDA Hospital is sometimes written as Taida, but TEDA refers to the Tianjin Economic Development and Technological Area in New Binhai where the hospital is located.

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